Experimental Investigation of Additive Effects of Nano-particles on Diesel and Biofuel powered Compression Ignition Engine

A brief outline of the area of research work proposed to be carried out in pursuance of the requirements for the award of the degree of

Doctor of Philosophy

Submitted by

Kumar Ratnakar

Dr. D. Ganeshwar Rao
Supervisor
Professor

Dr. Manoj Dixit
Co- Supervisor
Asstt. Professor

Head,
Department of Mechanical Engineering

Dean,
Faculty of Engineering

Department of Mechanical Engineering Faculty of Engineering
Dayalbagh Educational Institute (Deemed to be University)
Dayalbagh, Agra

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1. INTRODUCTION

There has been significant research going on for past many years in the area of fuel to develop some effective and alternate source. Biofuel, an alternate fuel, could be prepared with vegetable oils both from edible and non-edible in nature. Extensive research has been conducted for its characterization and analysis. Internal combustion (IC) engine powered by conventional diesel has shown positive results when fired with biofuels and their blends. The fuel modification consists of improvising fuel properties mainly combustible nature which is responsible for high fuel economy, better engine performance and low exhaust emissions.

Biofuels used with conventional diesel as blend has shown that it helps in reducing emissions but at the same time also requires to be optimized to explore its full potential.

The recent interest in the production of energy from biofules / biomass has focused primarily on technologies and applications that produce liquid fuels for the use of the transportation industry. Ethanol in its anhydrous form can be blended with gasoline which has become one of the most widely used biofuel. In the same manner, biodiesel (the methyl ester of plant oil) can be easily blended with as a substitute for diesel fuel. Its production and use have also become widespread in the recent past. Its use has the additional advantage of reducing emission of air pollutants, buildup of greenhouse gas and dependence on imported oil.

Biofuels or biodiesels, made from various crops as well as animal fat are renewable, bio- degradable, non-toxic and eco-friendly compared with fossil fuels. Currently, the sources of biodiesel outside Indian sub-continent mainly include soybean oil, sunflower oil, corn oil, used fried oil, olive oil, rapeseed oil, castor oil, lesquerella oil, milkweed (Asclepias) seed oil, palm oil and linseed oil [1,2,3]. In general, biodiesel derived from these sources can be defined as mono-alkyl esters of long chain fatty acids [4]. The mono-alkyl esters that are the main chemical species of biodiesel, has properties similar to diesel fuel [5]. It can be used in

modern diesel engines in its pure form (B100) or may be blended with petroleum diesel. The Government of India (GOI) approved the National Policy on Biofuels on December 24, 2009. **The policy encourages use of renewable energy resources as alternate fuel to supplement transport fuels and had proposed an indicative target to replace 20 percent of petroleum fuel consumption with biofuels (bioethanol and biodiesel) by end of 12th Five-Year Plan (2017). The New biofuel policy of Govt of India 2018 has also recommended to continue to blend minimum 20% biofuels. The scope of biofuels policy has encompassed to bioethanol, biodiesel and biosynthetic fuels. Government has also emphasized on use of waste cooking oil to large extent as far as possible.**

Unlike other countries, India is not using vegetable oils derived from rapeseed & mustard, soybean or oil palm for the production of biodiesel. It is because India is not self-sufficient in edible oils production and depends upon imports of palm oil and other vegetable oils in large quantities to meet the domestic demand. Utilization of non-edible seed oils extracted from trees and forest sources do not interfere with food security directly if the trees are grown on marginal/waste land, as they do not compete with food production. **Every year around 1.2 million tons of tree borne non-edible seed oils are produced in the country (GoI, 2008). In India, biodiesel is produced mostly from the non-edible oils extracted from the seeds of various plants.**

Indian sub-continent is rich in biodiversity and thus it is main cause that variety of non-edible oil seeds have been identified for biodiesel research. National mission on biodiesel has been vehemently promoting research in this area. Various research groups from India have identified number of seeds having potential to produce biodiesel in reasonably good quantity. In India biodiesel production from the non-edible oils can be obtained from plant species, such as Jatropha J. cucas (ratanjyot), P. Pinnata (karanj), C. Inophyllum (nagchampa), R. communis (castor), C. odollam (sea mango), Putranjiva roxburghii (Lucky beantree), Sapindus mukorossi (soapnut), H. brasiliensis (rubber tree), C. Inophyllum (polanga), Melia azedarach (syringa), S. chinensis (jojoba), Maduca Indica (mahua), Schleichera triguga (kusum). [6].

Biofuels are fuel produced from biomass, within a time frame sufficiently short to consider that their feedstock (biomass) can be renewed, contrarily to fossil fuels. Bio-diesel, as defined by the American Society for Testing and Materials (ASTM), is a fuel comprised of mono- alkyl esters of long chain fatty acids derived from vegetable oils or animal fats. Due to the great molecular similarities between bio-diesel and petroleum diesel, this alternative fuel has

a chance of fulfilling the technical requirements of diesel fuel [7]. It is a domestic, clean- burning, renewable liquid fuel that can be used in compression ignition engines with little or no modifications. The dominant bio-diesel production process, namely trans-esterification, typically involves the reaction of an alkyl-alcohol with a long chain ester linkage in the presence of a catalyst to yield mono-alkyl esters (bio-diesel) and glycerol.

The different approaches for fuel modification have also been implemented to improve fuel and engine characteristics and application of nano-particle as combustion catalyst has also shown several advantage like high combustion output, increase in energy density, short ignition delays and lesser pollutant emissions [8]. Application of nano-particles as catalyst has several advantages and it has been found to have enhance surface area to volume ratio which provides more contact surface area for rapid oxidation. Metal additives like iron (Fe), cerium (Ce), aluminum (Al) etc have been examined for combustion, ignition behavior, engine performance and pollutant emission studies.

Researchers indicate that most of the engines running with blended biodiesel or with added nano-particles, there is reduction in emissions of CO and HC, whereas the percentage of NOx increases. However, this behaviour has been shown to be different at different speeds, loads and blends.

2. LITERATURE REVIEW

World over research has been conducted on various biofuels for their use as standalone biodiesel as well as blends of diesel and biodiesels. However, simultaneously an emphasis has been given on its best possible utilization in internal combustion engines. This task is not a single step and single parameter oriented, but it involves variables from biofuels properties to engines parameters. Therefore, all the aspects make this research problem as a multi- objective or multi-parameter

problem.

2.1 Engine performance and emission characteristics of Compression Ignition Engine

Dawody et al. [9] have studied the combustion and emission parameters of single cylinder, four stroke, constant speed diesel engine operating on diesel oil and different blends of soybean methyl ester (SME). Investigations made experimentally and also theoretically using the simulation software. NOx reduction was obtained by adopting different strategies on the B20% SME.

Studies on Karanja based biodiesel provided higher BTE at higher load condition and higher BSFC with the increase in blend ratio [10].

Srivastava et al. [11] experimented different Karanja biodiesel blends using a two-cylinder CI engine. Pure biodiesel gives lower BTE than diesel fuel, but biodiesel blend gives higher BTE than pure biodiesel. Jindal et al. [12] found that Karanja biodiesel blend gives better BTE and BSFC than other biodiesels.

Study on Mahua biodiesel provided poor results in terms of engine performance. Most researchers found that it has high BSFC and low BTE [13]. However, some test conditions indicated higher thermal efficiency [14].

Dhar and Agarwal [15] studied the effect of Karanja biodiesel (Karanja oil methyl ester; KOME) and its blends on engine performance, emissions and combustion characteristics in a direct injection compression ignition (DICI) engine of a medium size utility vehicle with varying engine speed and load. Their study on comparative investigation of performance, emissions and combustion characteristics of Karanja biodiesel blends and mineral diesel showed that up to 20% Karanja biodiesel blend can be utilized in an unmodified DICI engine.

Sinha et al. [16] observed that maximum torque was either equal or slightly higher for the lower biodiesel blends (B05, B10, and B20) of rice-bran biodiesel and decreased slightly for

higher blends vis-à-vis mineral diesel at lower engine speeds in a direct injection (DI) diesel engine. At higher engine speeds, torque output was almost similar for all test fuels.

Mahanta et al. [17] reported higher BSFC for 20% Karanja biodiesel blend as well as higher brake

thermal efficiency (BTE) than mineral diesel at all engine loads. The exact change in performance and emission characteristics of engine with respect to conventional diesel varies considerably depending upon biodiesel properties, blend concentration and engine technology used. Karanja oil is a promising feedstock for producing biodiesel in India on large scale because it is well adapted to local climatic conditions and is available in good quantities throughout the country [18].

Ogunkoya et al. [19] conducted studies on renewable fuel on compression-ignition internal combustion engine and indicated slightly lower mechanical efficiency but better brake specific fuel consumption. Results from combustion showed shorter ignition delays for most of the renewable (deoxygenated) fuels. Combustion characteristics indicated lower peak in cylinder pressures, reduced rate of increase in cylinder pressure, and lower heat release rates for the renewable fuels.

Dhar and Agarwal [20] conducted studies on Karanja based biodiesel particularly for particulate matter based emissions. They studied the effect of Karanja biodiesel and its blends on particulate size-number distribution, size-surface area distribution and total particulate number concentration at various engine operating conditions. The findings indicated that peak number concentration of particulates increased with increasing engine speed for all test fuels. Smaller concentration of Karanja biodiesel (upto 20%) was effective in reducing the particulate number emissions.

2.2 Nano-particle added biofuel powered Compression Ignition Engine

Several researchers have done experiments with nano-doped biofuels and identified finding on improvement in engine characteristics and fuel emission reduction. From physics of nano particle added fuel point of view very few research studies have shown discussion on combustion enthalpy, ignition delay, lesser pollutant, flash point, fire point of fuel. Sajith et al. [21] have shown addition of cerium oxide nanoparticle to biodiesel fuels could significantly increase the flash point and fire point which makes it desirable for safe handling of fuel. Research studies have found that nanoparticles inclusion shows better properties when added in the size of nano scale. These particle shows tendency to improve high reactive surface area responsible for more combustion due to reduction in ignition

delays.

Mehregan et al. [22] attempted to numerically investigate the combustion characteristic of ethanol and n-decane liquid fuels with n-Al particles. It was found that with nanoparticles the flame temperature of both liquid fuels get reduced.

Ghanbari M et al. [23] demonstrates that the use of nano-diesel biodiesel blended fuel will increase the brake power and torque and decrease the brake specific fuel consumption. It was also found that the CO_2 and NOx concentrations were increased while the concentration of CO and HC were decreased when nano-biodiesel diesel blends are used.

Diesel finds its application as fuel in CI engine and for production of power. It is widely accepted that diesel combustion emits harmful pollutants which are responsible for environmental degradation as well as human health. Different strategies are adopted to mitigate the harmful effects of diesel combustion. In this regard biodiesel is considered as viable alternative to diesel. When liquid fuels processed with nano-particles the alternative fuel offers number of potential benefits over existing diesel and biodiesel fuels.

Some researchers have attempted to use nanofluid fuels directly in diesel engine to improve ignition and combustion properties of conventional diesel and biodiesels fuel and also investigated its overall effect on engine characteristics [24,25].

Experimental investigation was carried out to evaluate the performance and emission characteristics of diesel engine by using Calophyllum Inophyllum biodiesel blends with TiO_2

nano additives exhibits better engine performance and reduced emissions compared to the other fuels.[26]

Sivakumar et.al. has investigated the iron oxide (Fe_3O_4) nanoparticles blended biodiesel. It has enhanced the performance characteristics but also helped in the reduction of harmful emissions from compression ignition engines.[27]

Keskin et al. [28] have reported that metal oxide nanoparticles during combustion acts as oxygen donating catalyst which helps the oxidation rate of CO. In this regard an experimental study with tall oil biodiesel mixed with Mn and Ni nanoparticles were performed by the author to revealed

that CO emissions were lower for Mn & Ni blended biodiesel fuel as compared to diesel fuel.

Selvan et al. [29] have studied the additive effects of cerium oxide with neat diesel and diesel biodiesel ethanol blends which has shown better BSFC performance as compared to neat diesel/diesel biodiesel ethanol blends without CeO_2 additives.

Some researchers have performed experiments on variable speed engine to analyze the effect of engine speed on brake power. It was observed that BP of the engine increases with increase in engine speed. [30,31]

Fangsuwannrak et al. [32] in their experimental work studied the effect of titanium oxide (TiO_2) nanoparticle additives with palm biodiesel in an indirect injection diesel engine (IDI).

3. PROBLEM FORMULATION AND WORK PROPOSED

From literature review it is clear that studies have been carried out using biofuel and its blends with various parameters under consideration, but very few case studies have been reported with nano particle added bio-fuel and its performance evaluation. Hence, a very strong case is evolved to evaluate different types of nano-particle based biofuels and their blends.

It is also noted that engine has been run with varying the parameters such as compression ratio, EGR percentage, injection pressure, load etc. However, very few studies are available in literature indicating the use of all the parameters simultaneously in a single system.

If all parameters are used in tandem in an engine and study is carried out to use the obtained data for developing a mathematical model that is comprehensive and all inclusive, it would be possible to obtain realistic solutions which are verifiable in real life. Once such a model is available, further optimization will result in substantial improvement in the quality of solution.

4. OBJECTIVES

Biofuels obtained from different types of seeds are likely to have different oil content and chemical properties and exhibit different performance on engines. The engine performance with different sets of parameters is expected to be different. Hence it is proposed to run the engine with different kinds of biodiesel with a number of varying parameters; to develop a model with a view

to find an optimum solution for minimum exhaust emissions and maximum fuel efficiency and also to study the relative efficacy of biodiesel.

The specific objectives of the study are summarized as follows:

(i) To test the use of suitable nano-particle blended biofuel on various concentrations.

(ii) To perform tests on engines with different blends of biofuel and conventional fuel with varying operating parameters such as Load, Exhaust Gas Recirculation, Compression Ratio etc. and analyze the fuel consumption and exhaust emissions.

(iii) To study the thermo physical characteristics of nanoparticle added biofuels.

(iv) To modify engine hardware (like fuel injection) for testing of pure mono alkyl esters.

(v) To carry out the Optimization of nano-particle added biofuel powered compression ignition engine.

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